Simulation Based Comparative Study on EIGRP/ IS-IS and OSPF/ IS-IS

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Abstract— Developing of Internet networks and increasing demand of real-time applications, such as voice, video conferencing and routing algorithms play important roles in the real network in recent years. Considering rate and type of the demanding traffic, choosing of the routing protocol can cause the best performance in function of a network. In modern communication networks, routing protocols are used to determine the shortest path to the destination. Open Shortest Path First (OSPF), Enhanced Interior Gateway Routing Protocol (EIGRP) and Intermediate System to Intermediate System (IS-IS) are the dominant interior routing protocols for such networks. This paper presents a simulation based analysis of these protocols. We used the combination of EIGRP&IS-IS, OSPF&IS-IS routing protocols on the same network in order to reveal the advantage of one over the other as well as the robustness of each protocol combination and how this is measured. To carry out the network simulations, we used Optimized Network Engineering Tool (OPNET). The comparison analysis is based on several parameters that determine the robustness of these protocols. The routing protocol convergence time is one important parameter which determines the time needed by the routers to learn the new topology of the network whenever a change occurs in the network. The routing protocol which converges faster is considered a better routing protocol. Point-to-point link throughput, HTTP object response time, database response time and e-mail download response time are other parameters we used to measure the routing performance of the network.

Keywords— EIGRP, IGRP, IS-IS, OSPF, RIP, OPNET.

I. INTRODUCTION

Internet Protocol (IP) is the most widely used network layer protocol for interconnecting computer networks. Intra domain routing protocols, also known as Internet Gateway Protocols (IGP), organize routers within Autonomous Systems (ASs). Nowadays, the most widely used intra domain routing protocols are Open Shortest Path First (OSPF), Enhanced Interior Gateway Routing Protocol (EIGRP) and Intermediate System to Intermediate System (IS-IS).

This paper provides detailed simulation analysis of the robustness of OSPF/IS-IS and EIGRP/IS-IS routing protocols. We analyze the impacts of using OSPF and IS-IS together as compared to using OSPF alone or IS-IS alone on the same network topology. In the same manner, we analyze the impacts of using EIGRP and IS-IS together as compared to using IS-IS or EIGRP alone. The simulations are carried out by using the OPNET-Modeler simulator [3].

II. PROBLEM DESCRIPTION

Interior networks mainly use the following three routing protocols: EIGRP, OSPF and IS-IS. Due to its scalability, OSPF is used more often than EIGRP [1]. OSPF and IS-IS are link state protocols. These protocols consume high bandwidth during network convergence. Both protocols are relatively complicated to setup on the network but they are the preferred protocols for larger networks. On the other hand, EIGRP has a faster convergence time than OSPF and IS-IS, it can be used in different network layer protocols and it is relatively easy to setup on the network. However, EIGRP is a CISCO proprietary protocol, which means that it can only be used on CISCO products. In this paper, we will look at the advantages of using OSPF and IS-IS on one network and EIGRP and IS-IS on another network. The comparison analysis of the routing protocols will be performed on OPNET.

III. ROUTING PROTOCOL OVERVIEW

In IP networks, the main work of a routing protocol is to carry data packets and forwarded from one node to another. In a network, routing can be defined as transmitting data from a source to a destination by hopping one-hop or multi hop. Routing protocols should provide minimum two facilities: firstly selecting routes for different pairs of source/destination nodes and, successfully transmitting data to a given destination. Routing protocols are used to describe how routers communicate to each other, build routing tables, make routing decisions and share information among neighbors. Routers are used to connect multiple networks and to provide packet forwarding for different types of networks. The main aim of routing protocols is to find the optimum path from a source to a destination. A routing algorithm uses different metrics based on a single or on several properties of the path in order to determine the best way to reach a given network. Traditional routing protocols used in interior gateway networks are categories as Distance Vector Routing Protocols and Link State Routing Protocols.

3.1 Distance Vector Routing

As the name indicates, distance vector routing protocol advertise routes as a vector of distance and direction. Here, the distance is represented in terms of hop count metrics and direction is represented by the next hop router or exit interface. Distance Vector Routing (DVR) is based upon the Bellman Ford algorithm. In DVR, the paths are calculated using the Bellman Ford algorithm where a graph is built in which nodes takes position of the vertices and the links between the nodes takes position of the edges of the graph. In DVR, each node maintains a distance vector for each destination. The distance vector consists of destination ID, next hop and shortest distance. In this protocol, each node sends a distance vector to its neighbors periodically informing about the shortest paths. Hence, each node discovers routes from its neighboring nodes and then advertises the routes from its own side. For information about the routes each node depends upon its neighbor which in turn depends on their neighboring nodes and so on. Distance vectors are periodically exchanged by the nodes and the time may vary from 10 to 90 seconds. For every network path, when a node receives the advertisement from its neighbors indicating the lowest-cost, the receiving node adds this entry to its routing table and re-advertises it on its behalf to its neighbors.

Methods of Routing

Distance vector routing protocol is one kind of protocol that uses the Bellman Ford algorithm to identify the best path. Different Distance Vector (DV) routing protocols use different methods to calculate the best network path. However, the main feature of such algorithms is the same for all DV routing protocols. To identify the best path to any link in a network, the direction and distance are calculated using various route metrics. EIGRP uses the *diffusion update* algorithm for selecting the cost for reaching a destination. Routing Information Protocol (RIP) uses hope count for selecting the best path and IGRP uses information about delay and availability of bandwidth as information to determine the best path [6]. The main idea behind the DV routing protocol is that the router keeps a list of known routes in a table. During booting, the router initializes the routing table and every entry identifies the destination in a table and assigns the distance to that network. This is measured in hops. In DV, routers do not have information of the entire path to the destination router. Instead, the router has knowledge of only the direction and the interface from where the packets could be forwarded [5].

Properties of Distance Vector Routing

The properties of DV routing protocol include [1]

- DV routing protocol advertise its routing table to all neighbors that are directly connected to it at a regular periodic interval.
- Each routing tables needs to be updated with new information whenever the routes fail or become unavailable.
- DV routing protocols are simple and efficient in smaller networks and require little management.   DV routing is base on hop counts vector.
- The algorithm of DV is iterative.
- It uses a fixed subnet masks length.

Advantages and Disadvantages of DV Routing

DV routing protocol suffers from the problem of count to infinity and Bellman Ford algorithm has a problem of preventing routing loops [4]. The advantages of DV routing protocols are:

- Simple and efficient in smaller networks.
- Easy to configure
- Requires little management.
- The main disadvantages of DV routing protocols
- Results in creating loops.
- Have slow convergence.
- Problems with scalability.
- Lack of metrics variety.
- Being impossible for hierarchical routing.
- Bad performance for large networks.

3.2 Link State Routing

Link State Routing (LSR) protocols are also known as Shortest Path First (SPF) protocol where each router determines the shortest path to each network. In LSR, each router maintains a database which is known as link state database. This database describes the topology of the AS. Exchange of routing information among the nodes is done through the Link State Advertisements (LSA). Each LSA of a node contains information of its neighbors and any change (failure or addition of link) in the link of the neighbors of a node is communicated in the AS through LSAs by flooding. When LSAs are received, nodes note the change and the routes are recomputed accordingly and resend through LSAs to its neighbors. Therefore, all nodes have an identical database describing the topology of the networks. These databases contain information regarding the cost of each link in the network from which a routing table is derived. This routing table describes the destinations a node can forward packets to indicating the cost and the set of paths. Hence, the paths described in the routing table are used to forward all the traffic to the destination. Dijkstra's algorithm is used to calculate the cost and path for each link. The cost of each link can also be represented as the weight or length of that link and is set by the network operator.

By suitably assigning link costs, it is possible to achieve load balancing. If this is accomplished, congested links and inefficient usage of the network resources can be avoided. Hence, for a network operator to change the routing the only way is to change the link cost.

3.2.1 OSPF

Open Shortest Path first (OSPF) is a link state routing protocol that was initially developed in 1987 by Internet Engineering Task Force (IETF) working group of OSPF [17]. In RFC 1131, the OSPFv1 specification was published in 1989. The second version of OSPF was released in 1998 and published in RFC 2328. The third version of OSPF was published in 1999 and mainly aimed to support IPv6.

Characteristics of OSPF

Following characteristics are associated with OSPF [24].
- OSPF provides load balancing by distributing traffic through multiple routes to a given destination [24].
- It allows maximum flexibility and provides transfer and tagging of external routes injected into AS.
- It helps exchange information obtained from external sites.
- Runs directly over IP.
- Provides authenticated routing updates using different methods of authentication.
- It has low bandwidth utilization and ensures less processing burden on routers because updates are only sent when changes occur.

Advantages and Drawbacks of OSPF

The advantages of OSPF are
- OSPF is not a proprietary protocol.
- Fast and loop less convergence
- Low bandwidth utilization
- Precise metrics are supported and if needed multiple metrics can be used.
- Multiple paths are supported.
- External routes are represented separately.
- No hop count limit.
- Supports VLSM.
- Supports larger networks.

Drawbacks of OSPF are
- Complex to configure
- Memory overhead.
- Processing overhead is high when topology changes occur.

3.2.2 Intermediate system to Intermediate system (IS-IS) is a link state routing protocol introduced by ISO [5]. To exchange routing information, IS-IS routers calculate the cost for the route based on a single metric. IS-IS routing protocol is very similar to OSPF. IS-IS is designed to provide intra domain routing or routing within an area. IS-IS network includes end systems, intermediate system, areas and domains. In IS-IS network, routers are intermediate systems organized into local groups known as areas. Several area are grouped together to form domains. User devices are End systems. IS-IS and OSPF are link state routing protocols that can be used for larger networks. IS-IS uses Dijkstra algorithm to determine the shortest path and utilizes a link state database to route packets between intermediate systems. IS-IS usually use two level hierarchical routing in which a level 1 router can identify the topology in the area including every router and host. However, a level 1 router cannot know the identity of routers outside their area. Level 1 routers of are similar to OSPF intra area routers since it has no connections outside.

Advantages and Drawbacks of IS-IS
Advantages
- Fast convergence. For transmitting routing information, IS-IS utilizes a low number of packet types.
- Support large areas of several intermediate systems without degradation of SPF performance.
- It does not implement virtual links
- Scalable. Backbone is not an area in IS-IS but instead is a collection of contiguous ABRs.
- Simple to implement.

Drawbacks
- Metrics are 6 bit wide (0-63). Default metric is 10 if it is not manually specified.
- All areas in IS-IS networks are stub areas which may result in suboptimal routing between areas.
- All ISs must have identical views of an area.
- For node identification, NSAP addresses are needed in combination with Connectionless Network Protocol (CLNP) as an additional network layer protocol.

3.2.2 EIGRP

Enhanced Interior Gateway Routing Protocols (EIGRP) is a CISCO proprietary protocol and it is an enhancement of the interior gateway routing protocol (IGRP). EIGRP was released in 1992 as a more scalable protocol for medium and large scale networks. It is a widely used interior gateway routing protocol which uses Diffusion Update Algorithm (DUAL) for computation of routes. EIGRP is also known as hybrid protocol because it has the properties of a link state protocol for creating neighbor relationships and of a distance vector routing protocol for advertisement of routes.

Advantages and Drawbacks of EIGRP

EIGRP provides the following advantages

- Loop free routes are provided.
- It additionally saves a back up path to reach the destination.
- Multiple network layer protocols are supported
- Convergence time for EIGRP is low which in turn reduces the bandwidth utilization.
- Supports VLSM, discontinuous network and classless routing.
- Routing update authentication is supported by EIGRP.
- Topology table is maintained instead of the routing table and consist of best path and an addition loop free path.
- Drawbacks of EIGRP are
- It's a Cisco proprietary routing protocol.
- Routers from other vendors cannot utilize EIGRP.

IV Simulation Tool Used

In our dissertation work we are using the Optimized Network Engineering Tool (OPNET v16.0) software for simulating selected routing protocols. OPNET is a network simulator. It provides multiple solutions for managing networks and applications e.g. network operation, planning, research and development (R&D), network engineering and performance management.
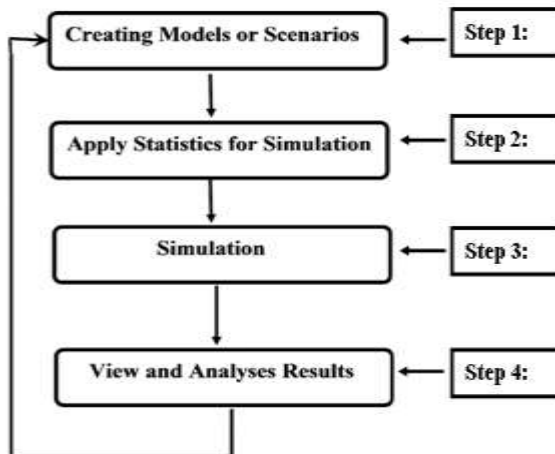

Figure: 4.1 Flow chart of OPNET

OPNET 16.0 is designed for modeling communication devices, technologies, and protocols and to simulate the performance of these technologies. It allows the user to design and study the network communication devices, protocols, individual applications and also simulate the performance of routing protocol. It supports many wireless technologies and standards such as, IEEE 2002.11, IEEE 2002.15.1, IEEE 2002.16, IEEE 2002.20 and satellite networks. OPNET IT Guru Academic Edition is available for free to the academic research and teaching community.

V. Simulation Scenarios

In our paper, we used five different scenarios. The scenarios are created based on the routing protocols presented. The network topology consists of the following network devices and configuration utilities:

5.1 OSPF Scenario

This scenario implements OSPF as a routing protocol on the selected network topology. As a first step, we created the network topology without a routing protocol and then, we duplicated it to five scenarios so that we could simulate OSPF, EIGRP, IS-IS, OSPF/IS-IS and EIGRP/IS-IS on each of them. So, on one of the duplicated scenarios, OSPF is configured as a routing protocol for the whole routers in the network. After configuring the routing protocol, we choose the statistics that will be viewed on the result.

These statistics are: OSPF Traffic received (bits/s), HTTP object response time, E-mail download response time, Database response time and point to point throughput

5.2 EIGRP Scenario
On this scenario, EIGRP is configured as routing protocol for the selected network topology. We used one of the duplicated scenarios with no routing protocol and configure EIGRP on it. Then, we choose the statistics that will be viewed on the result: EIGRP Traffic received (bits/s), EIGRP Convergence duration, HTTP object response time , E-mail download response time and point to point throughput.

5.3 IS-IS Scenario
On this Scenario, IS-IS is configured as routing protocol for the network topology. Then, we choose the statistics that will be viewed on the result: IS-IS Traffic received (bits/s), IS-IS Convergence activity, HTTP object response time, E-mail download response time , Database response time and point to point throughput.

5.4 EIGRP/IS-IS Scenario
One of the main focuses of our paper is to analyze the network that is configured with EIGRP and IS-IS routing protocols together and deduce the advantages of using both protocols together. This scenario is a little different from the others because two routing protocols are configured on the network.

As shown in Figure, some part of the network uses EIGRP and the other part uses IS-IS. Both protocols use route redistribution for exchanging route information to each other. Route redistribution is a feature that allows for the exchange of route information among multiple protocols and multiple sessions [3]. The characteristics of each routing protocols is analyzed, while using both protocols together.
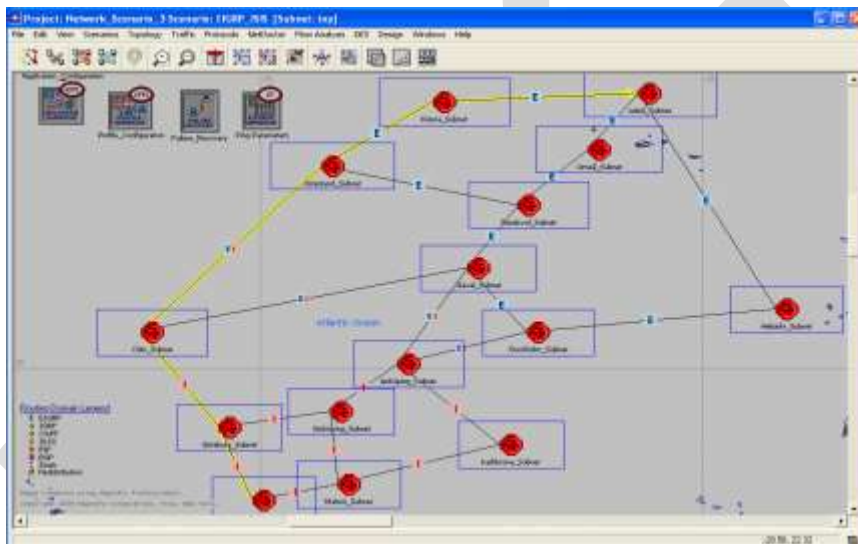

Figure: 5.1 EIGRP/IS-IS Scenario

The statistics chosen for this scenario: IS-IS Traffic received (bits/s), IS-IS Convergence activity , HTTP object response time, E-mail download response time, Database response time, EIGRP convergence activity, EIGRP traffic sent (bits/s) and point to point throughput (packet/s).

5.5 OSPF/IS-IS Scenario
The other main focus of our paper is the combination OSPF/IS-IS, which analyzes the implementation of OSPF and IS-IS together on the topology network. As shown in Figure, some part of the network uses OSPF and the other part uses IS-IS
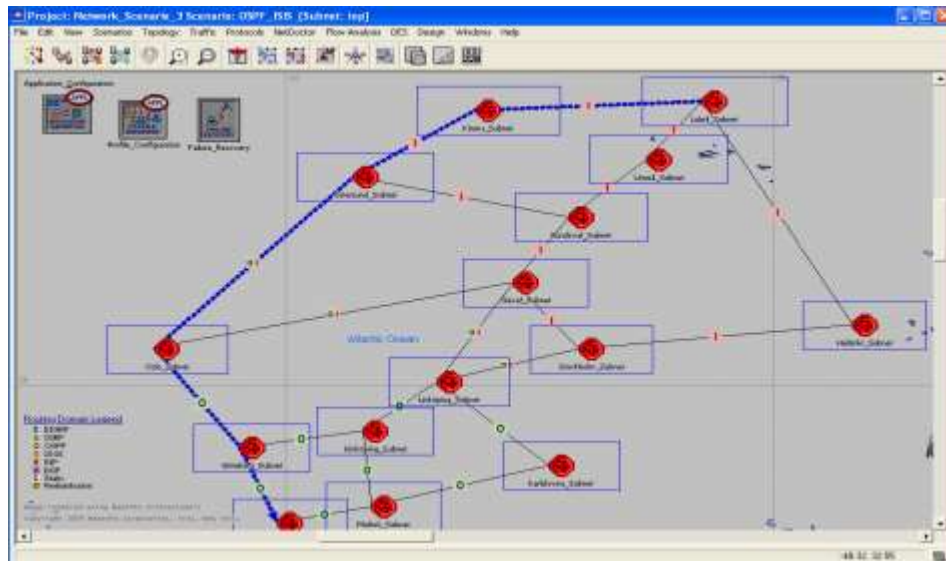
Figure: 5.2 OSPF/IS-IS Topology

VI. Simulation Result and Analysis

As we mentioned earlier, we have five simulation scenarios: OSPF, EIGRP, IS-IS, OSPF/IS-IS and EIGRP/IS-IS. This helps us compare one protocol with the other. So, we select a specific parameter and compare the results of all protocols on one graph based on the selected parameter. In all the scenarios, router are setup to fail at 250 s and 350 s.

6.1 OSPF Traffic

Figure 6.1 shows the OSPF traffic sent in bits per Sec. On the graph OSPF traffic is higher at the time of first convergence in OSPF/IS-IS protocol than in OSPF. At the time when router fails, there will be a network topology update; therefore the routers will exchange route information with the whole network. Again, the second time, when router fails, it will update the network tables, so there will be another route information exchange. At the second and third convergence, the OSPF traffic will be higher in OSPF than OSPF/IS-IS.
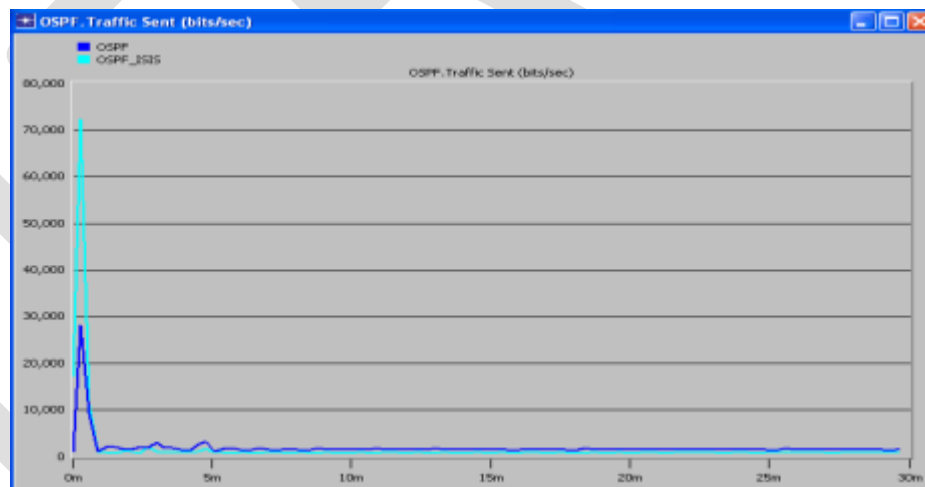

Figure 6.1: OSPF Traffic.

6.2 EIGRP Traffic

Figure 6.2 shows EIGRP traffic sent in bits/s. It is shown that during the time of convergence, the EIGRP traffic is much higher in EIGRP network than of EIGRP/IS-IS network. In EIGRP/IS-IS network, the EIGRP route information will be lower because the EIGRP traffic is exchanged within the interface that uses EIGRP protocol. The network that use EIGRP for the whole network will have more interfaces that use EIGRP, so there will be more EIGRP traffic than a network that use EIGRP and IS-IS in the network.
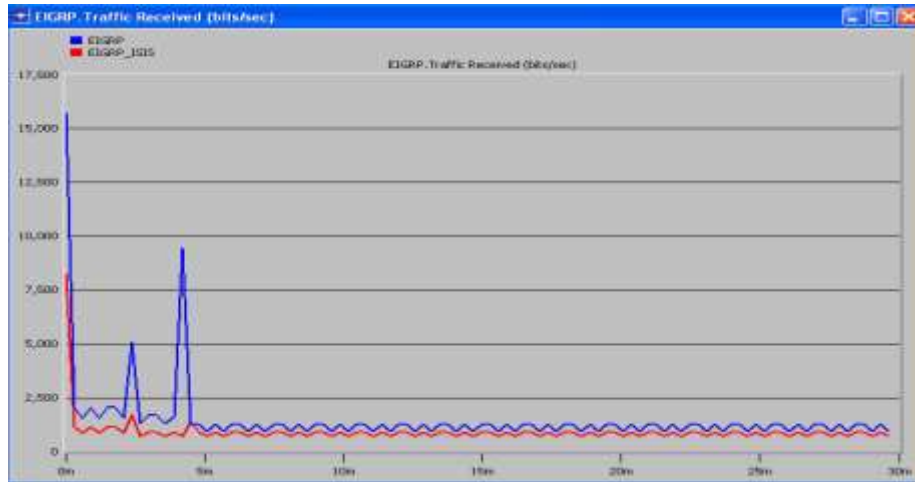
Figure: 6.2 EIGRP Traffic.

6.3 EIGRP Convergence Time

Figure 6.3 shows the convergence time of EIGRP in the network that uses EIGRP routing protocol and EIGRP/IS-IS routing protocol. As it's shown in Figure, the convergence time of EIGRP in EIGRP/IS-IS network is relatively smaller than the network that uses only EIGRP. EIGRP route information update will be advertised within the interface that use EIGRP routing protocol, since the interfaces enabled to use EIGRP are smaller in EIGRP/IS-IS than EIGRP, it will take a smaller time to update the topology table, routing table and neighbor table. The first convergence time of EIGRP/IS-IS is 5.9 s, whereas for EIGRP it is around 0.025 s. The second convergence time, it is 0.079 s for EIGRP, whereas for EIGRP/IS-IS it is 0.027 s. The third convergence time is 0.066 s for EIGRP, whereas for EIGRP/IS-IS it is around 0.007 s.
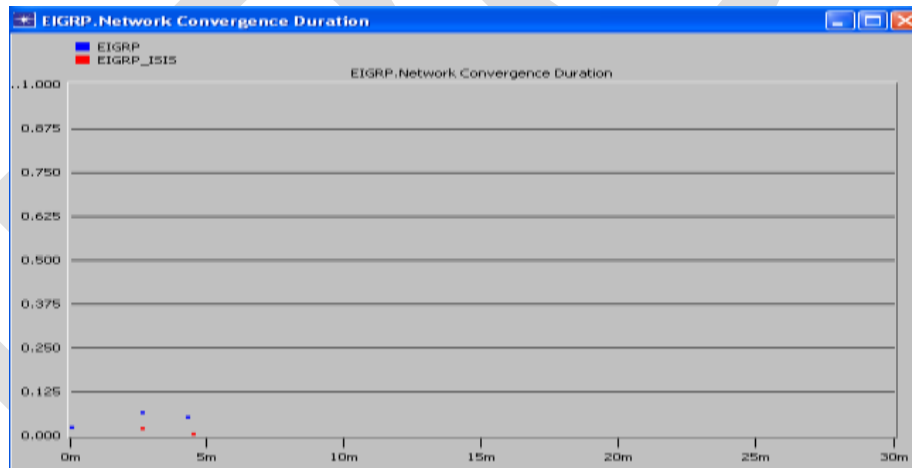

Figure: 6.3 EIGRP Convergence Time

6.4 IS-IS Convergence Time

As it is shown in Figure 6.4, the elapsed time to converge the network on IS-IS network is slower than OSPF/IS-IS network and EIGRP/IS-IS network. On the other hand, the network convergence time for EIGRP/IS-IS network is faster than the other networks. The first convergence time of IS-IS is 12 s, whereas for EIGRP/IS-IS is around 0.9 s and for OSPF/IS-IS is 13 s. The second convergence time of IS-IS is 11 s, whereas for EIGRP/IS-IS it is around 0.9 s and for OSPF/IS-IS it is 6 s. The third convergence time of IS-IS is 11 s, whereas for EIGRP/IS-IS is around 6 s and for OSPF/IS-IS is 7 s.
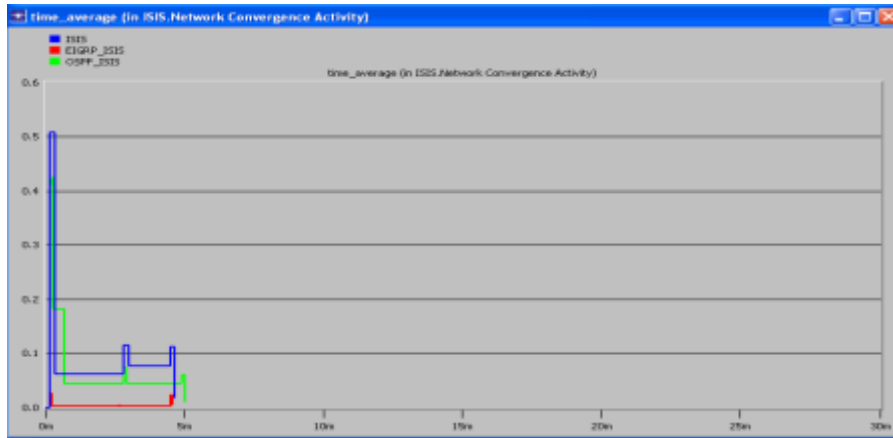
Figure 6.4 IS-IS Convergence Time

6.5 Database Query Response Time

Figure 6.5 shows the database query response time in the second scenario. The LAN network is able to access the database from the server, so in this scenario we show how the protocols affect the performance to access the database from the server. In the comparison of these protocols in database query response time, EIGRP/IS-IS shows a better response time than of the other protocols at the whole time. On the other hand, OSPF/IS-IS shows a slower response time than of all the other protocols. At the beginning, the response time of OSPF, IS-IS, OSPF/IS-IS and EIGRP is almost similar but as time increases, OSPF/IS-IS becomes slower in response time. On the other hand EIGRP shows better performance than the other three protocols. OSPF and IS-IS protocols show almost similar database response time in the whole time.
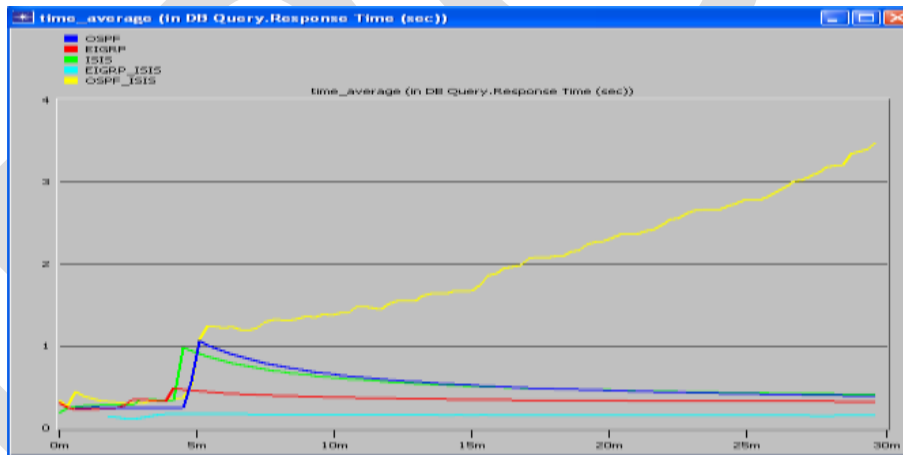

Figure: 6.5 Database Query Response Time

6.6 E-mail Download Response Time

E-mail application is heavily used by the users in the LAN network, the E-mail access is done from the mail server in the network. Figure 6.6 shows E-mail download response time in s. The graph shows that the EIGRP/IS-IS protocol performs very well for the whole simulation time. On the other hand, OSPF/IS-IS performs bad compared to the other protocols. In the first 4 minutes, IS-IS shows better E-mail download response time than of EIGRP and OSPF. After 4 minutes OSPF, EIGRP and IS-IS show almost similar performance for E-mail download response time.
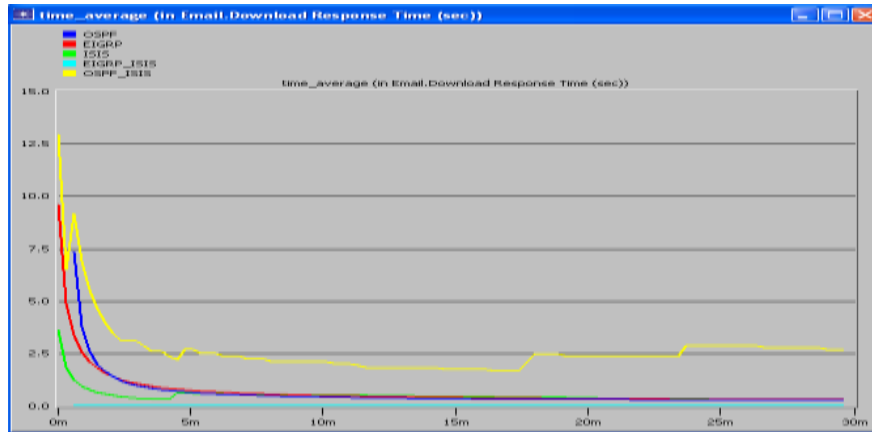
Figure: 6.6 E-mail Download Response Time

6.7 HTTP Object Response Time

Figure 6.7 shows HTTP object response time in s. Heavy HTTP application is used by the users in the network and the application service is supported by the server. The graph shows that EIGRP/IS-IS shows a shortest object response time in the whole simulation time. For the first 3 minutes, OSPF/IS-IS has a better object response time than of OSPF, IS-IS and EIGRP. But as time increases, OSPF/IS-IS object response time increases, and instead IS-IS become better than the other four protocols.

Figure: 6.7 HTTP Object Response Time
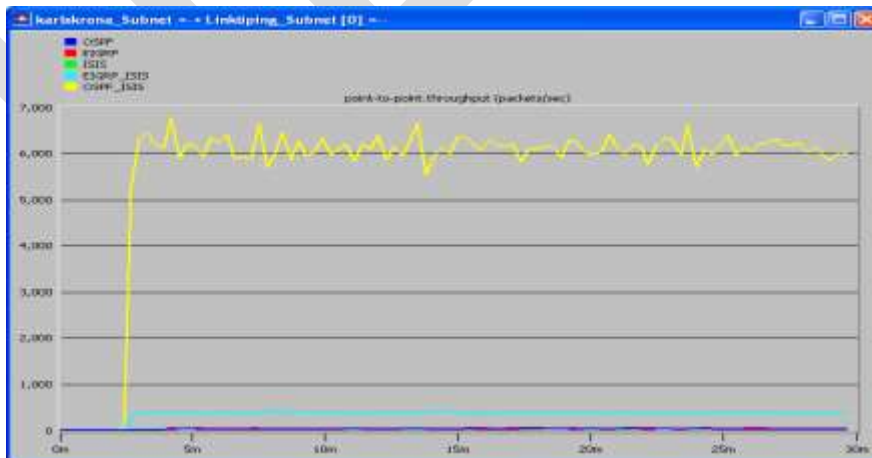
6.8 Throughput

Figure: 6.8 Throughput

Figure 6.8 shows point to point throughput between the Karlskrona router and Link router measured in packets/s. The graph shows OSPF/IS-IS has high throughput in this link. On the other hand IS-IS, OSPF, EIGRP/IS-IS and EIGRP have a lower packet throughput in this link. EIGRP/IS-IS has are relatively better performance on point to point packet throughput than of the other three protocols.

VII Conclusions and Future Work

The objective of this paper was to configure multiple routing protocols on a selected network topology and analyze the performance improvement of the network. We aimed to configure OSPF and IS-IS together in one network, then EIGRP and IS-IS together in one another network. After configuring the protocols we analyzed the network performance improvements as compared to the network that use OSPF alone, EIGRP alone or IS-IS alone. The OSPF traffic in the network using OSPF/IS-IS is smaller than of network using only OSPF. This indicates that the bandwidth utilization of OSPF is better and the link congestion probability is smaller in OSPF/IS-IS network than that of network using only OSPF. The EIGRP traffic in the network using EIGRP/IS-IS is lower than of network using only EIGRP. This indicates that the bandwidth utilization of EIGRP is better in the EIGRP/IS-IS network than that of network using only EIGRP. Convergence time of EIGRP in the network using EIGRP/IS-IS network is much faster than in the network using only EIGRP. Therefore the nodes in EIGRP/IS-IS network learn the topology faster than the nodes in the EIGRP network.

IS-IS convergence time in EIGRP/IS-IS network is much faster than in IS-IS network or OSPF/ISIS network. On the other hand, IS-IS network shows lower convergence time than the EIGRP/IS-IS network or the OSPF/IS-IS network. Then we conclude, EIGRP/IS-IS network learns all nodes in the whole network faster than of IS-IS network or OSPF/IS-IS network. And IS-IS network learns slower than of the other two networks. Database response time is better in the network which uses EIGRP/IS-IS combination as compared to other networks using OSPF, IS-IS, EIGRP, OSPF/IS-IS. Network using OSPF/IS-IS combination shows slower database response time. Therefore database access is much faster in EIGRP/IS-IS networks and very slow in OSPF/IS-IS network. The network using EIGRP/IS-IS shows faster HTTP object response time, E-mail download response time than of other networks using OSPF, EIGRP, IS-IS, OSPF/IS-IS. On the other hand network using OSPF/IS-IS combination shows slow response in both the cases. Hence, EIGRP/IS-IS provides the end users access to the HTTP applications and e-mails faster than networks using OSPF, EIGRP, IS-IS, OSPF/IS-IS. The overall throughput performance of all networks is similar at the beginning of the simulation. But after few minutes, network using OSPF/IS-IS combination shows much better throughput performance than of all other networks. In our paper, we analyzed the performance of different routing protocols and have found EIGRP/IS-IS performed better than the other protocols. So, as a future work, we recommend any interested researcher to combine EIGRP and IS-IS routing protocols performs on MANET and Hybrid networks, and make one advanced routing protocol. This can be done by analyzing the source code of each protocol and make a modification on the codes.

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